Design of a Battery Electric Town-Car

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Abstract: ***The purpose of this research is to contribute to the design and build of a battery electric town-car, which must be safe and road legal and capable of carrying two adults and a modest quantity of luggage and/or shopping. There are many decisions to be made, from things such as batteries and motors, to smaller things such as windscreen wipers and seat-belt positioning. This will incorporate a wide and varied range of engineering. It might be an issue due to the size and the amount of the batteries and if we are shortening the chassis this poses another problem. But we are certain all the batteries and components will fit. For that reason, we are going to test using CAD (computer aided design). For this design project a budget of £6000 has been set by the client for a small production run. With the entire customer requirements to consider it was decided that the Li-ion batteries best suit the power requirements and the weight/space limitations of this car. With these dimensions the controller will fit into the designated space. Based on the output figures we know this controller is capable of a top output of at least 40KW and a sustained output of at least 18KW. This is enough to meet the power requirements needed to start the car, accelerate at the required speed and drive it around at speeds up to 60mph.***

Keywords: Design, Li-ion batteries, electric car, customer requirement

1. Introduction

The use of the vehicles is a primary source of energy consumption and pollutant emissions worldwide. The energy consumed by numerous vehicles contributes to the majority of petroleum usage, and meanwhile billions of tons of airborne pollutants are emitted in the atmosphere.

In response to concerns over environmental degradation with the high cost of fuel, many countries propose regulations, which would require a progressively increasing number of automobiles to be zero emissions automobiles.

We have been asked to contribute to the design and build of a battery electric town-car, which must be safe and road legal and capable of carrying two adults and a modest quantity of luggage and/or shopping.

As a group we were asked to design and build a battery powered car. Each member of group contributed to the design and build of the car.

There are many decisions to be made, from things such as batteries and motors, to smaller things such as windscreen wipers and seat-belt positioning. This will incorporate a wide and varied range of engineering.

We will show evidence from the initial preliminary discussions to the end of the design period. This will include:

- A list of customer requirements;
- Consideration of those requirements, the technical implications and the effect they will have on the design of our car;
- A detailed list of engineering requirements;
- Production of a conceptual design;
- Evaluation of alternative concepts on available evidence;
- Selection of the optimum design solution

List of Customer Requirements

- Maximum speed: 60mph (26.8 mps)
- Range: 30 – 120miles
- Estimated cost: £ 6,000
- Carrying capacity: 2 adults + modest quantity of luggage and/or shopping
- It must be similar in physical size to a sports car or small family car
- Climb a 1-in- 4 hill at 30mph
- Start from rest on a 1-in-4 hill
- Cruise at 60mph on level ground
- Recharge battery: Endure for at least 30miles (100 desired) on single charge
- Battery powered
- Size: Mid range (hatchback)
- Safety: Road legal (passing SVA), Braking system (0.8G), Chassis (10G), Chassis strength (10G-vertical; 4.5 horizontal)
- Heating System
- Acceleration: 0 – 30mph in 3 seconds; 0 – 60mph in 12 seconds
- Very attractive styling
- The vehicle must have normal levels of internal comfort, attractive & useful instruments, etc
- Easy maintenance

Consideration of Customer Requirements and Technical Implications and Restrictions

The vehicle type VW Chassis needs the followings components to be considered:

- Engine: engine block, cylinders, cooling system;
- Gearbox: clutch, gearbox, steering;
- Driveline: chain drive, differential, front and rear axles, brakes;
- Suspensions: springs, rods, shock absorbers, connections, wheels, tyres;
- Chassis: fame, body, driver’s seat, driver protection, crush zone;
- Electrical system;
- Starter, cooling fan and fan belt, seat belt.

The vehicle has a chassis and a ground clearance to prevent any portion of car from touching the ground during track events.

The steering system affects two wheels and the braking system acts on all four wheels, using anti-lock braking system.

The gear box has four forward and one reverse speeds and the engine will be water cooled.

As far as the driver protection is concerned, the driver is protected against rollover and collision, requiring two roll hoops which are braced, a front bulkhead with crash zone, and side protection. The exhaust is directed so that the driver is not subjected to fumes of any speed.

There are many engineering requirements linked to our particularly requirements. In terms of speed and acceleration we have to make the car light and air resistant. So we have decided to stick to a weight of 1250Kg, this is due to our calculations to find its top speed. There are some restrictions to this because our batteries are 38Kg each and therefore will add heavily to the weight but can cause and advantage if they are placed in the right places.

We have chosen to go with a Volkswagen beetle chassis to use as the foundation because we found our other options inferior. This posed a problem with the body shell we were using because the chassis was too big for the shell there for we will have to cut the chassis down. But the job we are going to do will enhance the strength of the chassis.

Like the Volkswagen beetle engine we are placing our motor at the back, because we have no support. We have to make sure the motor is kept in place and not bouncing about (This all depend on the use of top quality bolts). We found that one bolt can take up to 100Kg. If we were using 4 bolts might be sufficient.

The materials we are using in this vehicle are mostly steel. This is due to its durability and strength. Other materials might vary. We plan to make the car as comfortable as possible therefore we are going to attach a heater but this mean we will have to make plans for where the wires are going to go. There will be suitable and efficient equipment in the car.

As stated before it might be an issue due to the size and the amount of the batteries and if we are shortening the chassis this poses another problem. But we are certain all the batteries and components will fit. For that reason, we are going to test using CAD (computer aided design).

List of Engineering Requirements

Vehicle type

- Body style: VW Chassis

a. Vehicle sizes: Overall height - 1.20m

Overall length - 3.77m
Wheel to Wheel – 2.27m
Trail – 1.50m
Booth – Length – 0.79m
Width – 1.04m
Height (highest) – 0.65m
Height (shortest) – 0.48m
Electric drive system

b. Power supply: electric
c. Recharge: Domestic supply
d. Minimum storage capacity: 43.2 MJ ̃14.4 KWH

Battery System

e. Type: Lithium ion
f. Charging: 3 – 4 hours

Performance

g. Range: 30 – 120miles
h. Total maximum weight: 1250Kg (incl., mass of passengers, mass of luggage and/or shopping, battery, chassis, engine, etc)
i. Force of drag: 360 N
j. Power of drag: 9.648 Watt
k. Park power: 41,906 Watt
l. Cruising @ 30: 1200s
m. Acceleration: 30
n. Deceleration: 30
o. Hill climbs: 500m
p. Descents: 500m
q. Cruising power@30: 4Kw
r. Cruising energy: 4.8 MJ
s. Acceleration power: 112 KJ
t. Acceleration energy: 3.3 MJ
u. Average power demand: 14.4 MJ

2. Evaluation and Design Solution

As part of our requirements, the car had to look the part. The exact quote was ‘sex on wheels’. This left us with a few choices. We could design and make a car right from the chassis to the bodywork. Another choice was to buy an existing car then strip it out and put our own batteries, plus everything else to go with it. The last option was presented to us by our tutor Dr Steven Wright. The college had body moulds for a Porsche 356 roadster.

We all agreed that the Porsche body shell was probably the best looking car for our budget. After agreeing that we thought that this was the best way we wanted to go, we started to gather information on a chassis to use. We were told that the body shell was designed to fit onto a power metro chassis. We were also told that the college had a metro chassis we also discovered that there were a number of others available, including a VW beetle chassis.

We couldn’t rush into this decision so we decided to measure up the Porsche. We measured the wheelbase, the width of the shell, the engine space and various other measurements. Whilst we were there we also measured up a rover metro and the beetle chassis.

Both of these chassis had upsides and downsides. The metro measured up perfectly, however we found that the engine space was very small and hard to work in and maintain. Easy maintenance was one of our requirements.

The beetle on the other hand had plenty of space to work in with room to run our wiring systems through the car. However the down side was that the wheelbase was 4 inches too long, meaning the wheels would not fit into the arches in the bodywork. This would require cutting the chassis down.

Sometime later when we re-grouped we discussed the issues with the chassis and tried to decide which would be the best to use. We all agreed that working in the open space in the beetle would be more favourable. The task of cutting and welding the chassis was a big sticking point. This was when I informed our group that I served an apprenticeship and that I am a skilled fabricator/welder with 10 years experience in the industry. After hearing this, and also the fact that I was willing to perform the task everyone unanimously decided to use the beetle chassis.

Selection of Alternative Concepts on Available Evidence

For this design project a budget of £6000 has been set by the client for a small production run. The design specifications also include:

- Carrying capacity: 2 adults + modest quantity of luggage and/or shopping
- It must be similar in physical size to a sports car or small family car
- Size: Mid range (hatchback)
- Safety: Road legal (passing SVA), Braking system (0.8G), Chassis (10G), Chassis strength (10G-vertical; 4.5 horizontal)
- Heating System
- Very attractive styling
- The vehicle must have normal levels of internal comfort, attractive & useful instruments, etc
- Easy maintenance

The decision was made to use the Porsche 356 Roadster moulds already available to make a fibre-glass body that meets all of the above specifications and also can reduce costs. The colour can be chosen by the client. Using the body moulds this way means the whole body can be removed by a few bolts for easy maintenance. It has two seats, space for luggage and the design allows for the addition of a soft-top roof to make it into a convertible.

With this decision made, the dimensions of the body shell would affect the choice of chassis. Again, the decision was made, with consideration of the budget, to use an existing chassis from a scrap car and fit the body over it. There were two chassis available: a VW beetle or a Rover Metro.

Although the shell is actually designed to fit over a metro, it was decided to modify the beetle chassis and use that. The factors that influenced this decision were:

Safety, the VW had a sturdy and full chassis, in making modifications which would involve shortening the chassis by 4” and re-welding, we could actually strengthen the chassis even further Space, there is plenty of storage space for the batteries and other components. There is a large engine space to accommodate the motor.

With the extra space fitting and installing all of the necessary parts for and electric car will be easier, also it will allow for easier maintenance as per brief.

This solution also allows for using the existing brakes, steering and transmition thereby reducing costs and also helping to ensure the vehicle is road legal.

Batteries

The nest major decision was the batteries. There are many different types available, some factors to consider in selecting the appropriate one were that the customer required

- Maximum speed: 60mph (26.8 mps)
- Range: 30 – 120miles
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- Cruise at 60mph on level ground
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A consideration of the various batteries available would have to include the implications of these requirements.

The standard lead-acid batteries normally used in cars are not suitable for this as they become unstable under high energy demand.

Other batteries available:

NiCad: NiCd cells are available in the same general purpose physical sizes as alkaline batteries, from AAA through D, as well as several multi-cell sizes, including the equivalent of a 9 volt battery. Compared to lead-acid, NiCd batteries have a much higher energy density. This means that, for a given battery capacity, a NiCd battery is smaller and lighter than a comparable lead-acid battery. So this is good, given that size and weight are an important consideration in this project. One major drawback with the NiCad batteries is what’s known as the **memory effect**, or **lazy battery effect.** NiCd batteries gradually lose their maximum energy capacity if they are repeatedly recharged after being only partially discharged. The battery appears to "remember" the smaller capacity. This problem makes the NiCad battery unsuitable to power this car because there is no guarantee that the battery would always be fully discharged before each recharge.

NiMH: A NiMH cell can have two to three times the capacity of an equivalent size Nickel-cadmium battery. NiMH batteries are commonly considered to have lower environmental impact than NiCd batteries, due to absence of toxic cadmium. There batteries have the ability to be recharged many times and have already been used successfully in hybrid cars such as the GM Saturn Aura and the Chevrolet Malibu hybrid. However, Lithium ion batteries have a higher energy density than nickel-metal hydride batteries.

Li-ion: They are currently one of the most popular types of battery for portable electronics, with one of the best energy-to-weight ratios, no memory effect, and a slow loss of charge when not in use. In addition to uses for consumer electronics, lithium-ion batteries are growing in popularity for defence, automotive, and aerospace applications due to their high energy density. Lithium-ion batteries are available in a wide variety of shapes and sizes so as to efficiently fill available space in the devices they power.

Li-ion batteries are lighter than other equivalent secondary batteries—often much lighter. A key advantage of using Li-ion chemistry is the high open circuit voltage that can be obtained in comparison to aqueous batteries (such as lead acid, nickel metal hydride and nickel cadmium) Li-ion batteries do not suffer from the memory effect mentioned earlier.

With the entire customer requirements to consider it was decided that the Li-ion batteries best suit the power requirements and the weight/space limitations of this car.

Motor / Controller

This car will use an AC motor with a controller package from Everything-EV.com. The controller has

- Nominal operation voltage: 36V-96V
- Continuous current rating: 200A for 1hr
- RMS current: 450a max for 1min.

Dimensions:

Length 320mm
Width 200mm
Height (inc.terminals) 56mm

With these dimensions the controller will fit into the designated space. Based on the output figures we know this controller is capable of a top output of at least 40KW and a sustained output of at least 18KW. This is enough to meet the power requirements needed to start the car, accelerate at the required speed and drive it around at speeds up to 60mph.

The use of the VW chassis means that the original steering controls and breaking system can be retained. This will keep the costs down but also adds to passenger safety as theses are already tested to meet the legal road safety requirements.

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